Bird assemblages in relation to habitat measures in Gregory National Park, Northern Territory.

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Abstract

At 142 sites in the northern half of Gregory National Park, Northern Territory, vegetation characteristics were measured, and topographic and environmental features recorded at the same time that bird species were recorded (February to March, 1986). One hundred and four bird species were recorded.

A broad relationship existed between bird distribution and the inter-related parameters of floristic composition and structure of the vegetation. Bird composition was related to habitat categories of mixed species forests on mesa escarpments or riverine environments, eucalypt woodlands on plains, and eucalypt low open-woodlands on mesa slopes. These broad relationships were distorted by habitat locations, however, because similar vegetation from the Bullita and Victoria River Crossing areas supported different bird species.

The plains habitats had a higher number of bird species per hectare than the riverine habitats and the mesa tops. The Brown Honeyeater was the most abundant species while the Peaceful Dove occurred in the most habitats. The survey method was time efficient and effective but there should have been a more even sampling of the different areas defined from photo-patterns. At least some species (e.g. raptors) were undersampled and this may have hampered interpretation.

Introduction

The classification of vegetation usually by structure or dominant species and, sometimes, subsequent mapping of vegetation units often precedes the investigation of fauna of an area. Frequently the vegetation communities are recorded and then the birds associated with them are listed (e.g. Kikkawa 1968, 1982; Kikkawa *et al.* 1981; Kikkawa & Webb 1967). More recently, vegetation communities have been defined using statistical techniques and then visited repeatedly to define the birds associated with them (e.g. Braithwaite 1985; Woinarski *et al.* 1988). A vegetation survey of Gregory National Park in the Victoria River district of the Northern Territory (Fig 1) provided the opportunity to look at bird assemblages and to test whether habitat characteristics determined their distribution. This is the first study of the relationship between birds and vegetation in the western part of the Northern Territory.

Methods

The area

The climate of this region is monsoonal with rain (618 - 813 mm annually) falling for up to five months (predominantly December - February). (Further details on climate are included in Bowman *et al.* 1988.) Much of the area, particularly at the north-eastern end, consists of steep tablelands and hills with shallow soils (Stewart 1970). Soils are deeper on the lower slopes and river flats where they are usually of cracking clay. The region (about 16°S), with its predominantly low open woodland, falls in the transition zone between the taller denser forests and woodlands to the north and the more arid vegetation to the south (Gillison 1983).

Data collection

(i) Vegetation sampling

Landsat imagery at a scale of 1:250,000 was interpreted visually to produce a map of gross land types. From this, two representative areas of about 25 km2 were selected near Victoria River crossing (towards the north of the Park) and Bullita homestead (towards the centre) for intensive study. To classify the vegetation, 328 (100 m2) quadrats were placed (181 at Victoria River and 146 at Bullita) within

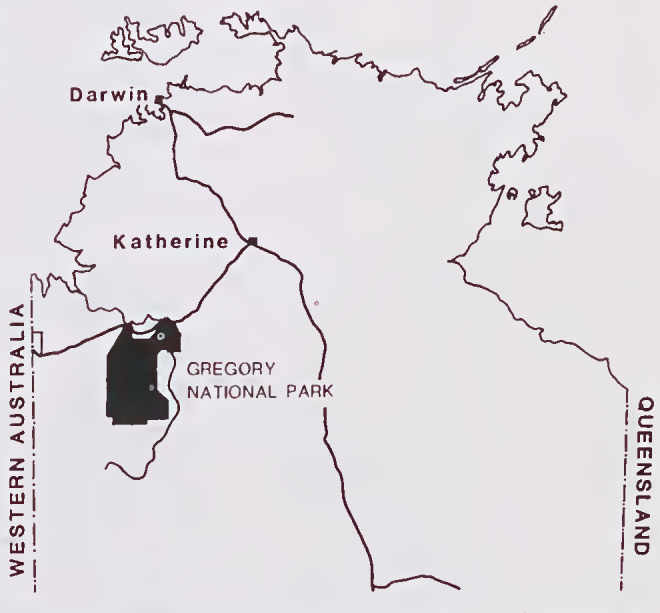

Figure 1. Map of the Northern Territory showing the location of Gregory National Park.

identified photo-patterns using a combination of systematic sampling of tracks, field traverse and helicopter landings during late February and early March 1986. Two teams, working in tandem, recorded all the vascular plant species in each quadrat, vegetation structure and major environmental parameters (topographic position, geology, soil texture, rock cover and slope). (The methods of the vegetation survey are reported more fully in Bowman *et al.* 1988.)

The subsequent numerical classification of the vegetation data identified 13 plant communities from the area near Victoria River crossing and 10 communities from the Bullita homestead area. The communities were found to be associated significantly with landform geology and could be grouped into landform complexes: riverine, plain, undulating terrain, and mesa plateau, slope or rim and escarpment (Table 1).

(ii) Bird sampling

One member (SCT) of one of the teams recorded the birds present at each site in about 100 m x 100 m, the area used to measure the basal area of the trees. This area included the vegetation quadrat and was perceived to be homogeneous with it. The area was searched thoroughly for about 15 minutes and presence of a species was scored on the basis of sight or call. Birds were censused throughout the day except between 1300 and 1400 h. Birds were conspicuous throughout the day because many were breeding.

Sampling was carried out at 142 sites which encompassed 20 of the 23 vegetation communities which were subsequently defined by floristic analysis. The number of bird sampling sites per vegetation community varied from 1 to 26.

Data analysis

The distribution of birds across the vegetation communities was considered in three ways.

(i) Comparison of sites by classification of bird species composition. Presence/absence of bird species from the 142 sites visited was stored on the ecological data base system Ecopak (Minchin 1986). Numerical analysis was carried out using the Numerical Taxonomy Package (NTP - Belbin *et al.* 1984).

The compositional similarity of sites was derived from the presence/absence lists of birds using the Bray Curtis association index. From this matrix the sites were clustered using the agglomerative hierarchical classification procedure WPGMA (Weighted Pair Group Mean Arithmetic), after the UPGMA (Unweighted Pair Group Mean Arithmetic) procedure was found to result in excessive 'chaining' with no clearly discernible groups. A dendrogram from the fusion table was generated. The final groups were then decided after examining bird species membership and their relationships with environmental parameters.

(ii) Comparison of vegetation communities by ordination of bird species composition. A parallel analysis was carried out to determine the relationship of the 20 vegetation communities, encompassed by the bird sampling, based on their bird species composition. Sites were agglomerated by vegetation unit to give percent frequency of bird species by vegetation unit. The relationship between the bird composition of the vegetation communities was portrayed by ordinating the 20 agglomerated sites using the Detrended Correspondence Analysis (DCA — Hill & Gauch 1980). The resulting ordination was related to vegetation and other environmental attributes.

Table 1

Summary of community number, structure, dominant plant species and topographic position of communities surveyed for birds, Gregory National Park, N.T. (after Bowman *et al.* 1988).

Community Number	Structure	Dominant Species	Mode Topographic Position
		Victoria River Area	
1	low open-woodland	*Eucaluptus dichromophloia, E. miniata, Plectrachne pungens*	mesa top
2	low woodland	*E. dichromophloia, Erythrophleum chlorostachys, P. pungens*	mesa top
3	woodland	*E. miniata, Terminalia latipes, P. pungens*	mesa rim and gully
4	forest	*Livistona* sp. *nova.*, mixed species	mesa gully
5	woodland	*E. tectifica, Lysiphyllum cunninghamii,* tall grasses	plain
6	low open-woodland	*E. tectifica, Er. chlorostachys,* tall grasses	plain
7	open-woodland	*E. tectifica, E. terminalis,* tall grasses	plain
8	low woodland	*Er. chlorostachys, E. tectifica, P. pungens*	mesa side
9	open-forest	*Strychnos lucida, Ziziphus quadriloculare*	mesa/ephemeral water course
10	low woodland	*Melaleuca argentea, Lophostemon grandiflorus*	riverine
11	woodland	*E. camaldulensis, Nauclea orientalis*	riverine
12	closed-forest	*M. symphiocarpa*	mesa gully
		Bullita Area	
14	woodland	*L. cunninghamii, E. tectifica, Adansonia gregorii, E. pruniosa,* tall grasses	plain
15	open-woodland	*L. cunninghamii, E. tectifica,* tall grasses	plain
16	low open-woodland	*E. brevifolia, P. pungens*	mesa side
17	low open-woodland	*E. dichromophloia, P. pungens*	mesa top
18	tall shrubland	*Acacia* spp., tall grasses	variable
20	open-forest	*T. platyphylla, L. grandiflorus,* tall grasses	riverine
21	low closed-forest	*S. lucida, Celtis philipensis*	mesa rim
23	low open-woodland	*E. ferruginea, E. brevifolia, P. pungens*	mesa top

(iii) Comparison of feeding niche, species richness and habitat breadth.

Birds were classified on the basis of feeding niche (determined from numerous observations and Schodde & Tidemann 1986) and tested for association with the vegetation and bird groups. Birds were classed as aquatic [Q], raptorial [R], granivorous [S], insectivores — ground [G], feeders at flowers [B], insectivores — aerial [A], insect and fruit feeders [F], and insectivores — foliage [I].

Mean species richness for birds for each vegetation group was calculated if two or more bird sites were sampled from the group. Habitat breadth (B) measures were calculated for any species that was found in at least 3 of these communities using $B=1/(P_i^2)$, where P_i is the number of times a species occurs in vegetation unit i divided by the total occurrences of the species over all vegetation units (Levins 1968). A comparison was made between the habitat breadths of birds recorded both in different habitat types near Darwin (Woinarski *et al.* 1988) and in this study. The correlation between the scores for birds in both habitats was calculated.

Results

A total of 104 bird species was recorded in the 142 samples (Table 2). Of these, 66 were recorded on more than four occasions. The most frequently observed species were the Brown Honeyeater (n=47), Peaceful Dove (n=46), Weebill (n=39), Mistletoebird (n=37) and Pied Butcherbird (n=36) (Table 2).

Table 2

Bird species recorded in the Victoria River and Bullita Areas of Gregory National Park, NT: sites with records of particular bird species expressed as a percentage of total sites (n) in each major plant community (vegetation/geological category) as defined by Bowman *et al.* 1988. The number of records of each bird species appears in brackets following its name. Feeding niche is defined as follows: Q = aquatic, R = raptorial, G = insectivore (ground), S = seed eater, B = feeders at flowers, I = insectivore (foliage), A = insectivore (aerial), F = insect and fruit feeder. Species richness and habitat breadth are defined in the text. Figures in brackets below habitat breadth figures are re-calculations of habitat breadth from Woinarski *et al.* (1988) for birds in the Darwin region.

Bird Species	Feeding Niche	Plant Communities (refer Table 1)								Habitat Breadth
		Mesa rim & escarpment		Riverine		Mesa Top		Plains		
		Victoria River Comm. Nos. 3, 9, 4, 12 n = 19	Bullita Comm. No. 21 n = 1	Victoria River Comm. Nos. 10, 11 n = 8	Bullita Comm. No. 20 n = 6	Victoria River Comm. Nos. 1, 2, 8 n = 34	Bullita Comm. Nos. 16, 17, 23 n = 5	Victoria River Comm. Nos. 5, 6, 7 n = 26	Bullita Comm. Nos. 14, 15, 18 n = 43	
Little Pied Cormorant (2) *Phalacrocorax melanoleucos*	Q			25						
Darter (1) *Anhinga melanogaster*	Q			12.5						
White-faced Heron (1) *Ardea novaehollandiae*	Q								2.3	
Black Kite (4) *Milvus migrans*	R			25		2.9		3.9		0.195 (5.69)
Whistling Kite (3) *Milvus sphenurus*	R								7.0	
Brown Goshawk (3) *Accipiter fasciatus*	R			12.5		2.9			2.3	0.373 (5.69)
Spotted Harrier (1) *Circus assimilis*	R								2.3	
White-bellied Sea-Eagle (1) *Haliaeetus leucogaster*	R			12.5						
Wedge-tailed Eagle (2) *Aquila audax*	R					2.9	20.0			
Brown Falcon (3) *Falco berigora*	R					2.9	20.0	3.9		0.259 (3.83)
Australian Kestrel (1) *Falco cenchroides*	R						20.0			
Peregrine Falcon (1) *Falco peregrinus*	R	5.3								
Brown Quail (2) *Coturnix ypsilophora*	S			12.5				3.9		
Chestnut-backed Button-quail (2) *Turnix castanota*	S							3.9	2.3	
Kori Bustard (1) *Ardeotis kori*	G								2.3	
Brolga (1) *Grus rubicundus*	Q							3.9		
Bush Thick-knee (1) *Burhinus grallarius*	G							3.9		
Crested Pigeon (8) *Geophaps lophotes*	S					2.9		3.9	14.0	0.376
Spinifex Pigeon (6) *Geophaps plumifera*	S			12.5		2.9			9.3	0.415
White-quilled Rock-Pigeon (1) *Petrophassa rufipennis*	S	5.3								
Bar-shouldered Dove (19) *Geopelia humeralis*	S		100	37.5	33.3	5.9	20.0	15.4	14	0.458 (9.23)
Diamond Dove (5) *Geopelia cuneata*	G	5.3				2.9		3.9	4.6	0.476

Table 2 (cont.)

Bird Species	Feeding Niche	Plant Communities (refer Table 1)								Habitat Breadth
		Mesa rim & escarpment		Riverine		Mesa Top		Plains		
		Victoria River Comm. Nos. 3, 9, 4, 12 n = 19	Bullita Comm. No. 21 n = 1	Victoria River Comm. Nos. 10, 11 n = 8	Bullita Comm. No. 20 n = 6	Victoria River Comm. Nos. 1, 2, 8 n = 34	Bullita Comm. Nos. 16, 17, 23 n = 5	Victoria River Comm. Nos. 5, 6, 7 n = 26	Bullita Comm. Nos. 14, 15, 18 n = 43	
Peaceful Dove (46) *Geopelia placida*	S	10.5	100	50	83.3	26.5	40	46.2	25.3	0.716 (5.6)
Red-tailed Black-Cockatoo (5) *Calyptorhynchus banksii*	S			12.5	16.7		20		4.6	0.442
Cockatiel (5) *Leptolophus hollandicus*	S					2.9		3.9	7.0	0.320
Sulphur-crested Cockatoo (4) *Cacatua galerita*	S							11.5	2.3	
Little Corella (6) *Cacatua pastinator*	S			25				7.7	4.6	0.25
Galah (10) *Cacatua roseicapilla*	S					11.8		11.5	7.0	0.46
Rainbow Lorikeet (17) *Trichoglossus haematodus*	B			12.5	16.7	14.7		11.5	15.3	0.613 (6.36)
Varied Lorikeet (5) *Psitteuteles versicolor*	B				16.7			3.9	6.9	0.317
Red-winged Parrot (14) *Aprosmictus erythropterus*	S	10.5			50	2.9	20	3.9	14	0.373 (4.5)
Budgerigar (6) *Melopsittacus undulatus*	S					5.9		15.4		
White-cheeked Rosella (3) *Platycercus eximius*	S	5.3				2.9		3.9		0.422
Pallid Cuckoo (1) *Cuculus pallidus*	I								2.3	
Brush Cuckoo (4) *Cacomantis variolosus*	I				33.3				4.6	
Horsfield's Bronze-Cuckoo (8) *Chrysococcyx basalis*	I					5.9	20	3.9	9.2	0.426
Common Koel (5) *Eudynamys scolopacea*	I								12.3	
Channel-billd Cuckoo (1) *Scythrops novaehollandiae*	I							3.9		
Pheasant Coucal (6) *Centropus phasianinus*	I	5.3		12.5		2.9			7.0	0.399
Rufous Owl (1) *Ninox rufa*	R								2.3	
Southern Boobook (1) *Ninox boobook*	R					2.9				
Barking Owl (1) *Ninox connivens*	R							3.9		
Tawny Frogmouth (2) *Podargus strigoides*	G				16.7				2.3	
Fork-tailed Swift (1) *Apus pacificus*	A					2.9				
Blue-winged Kookaburra (14) *Dacelo leachii*	G		100	50		5.9	20	11.5	7.0	0.366 (6.35)
Sacred Kingfisher (10) *Todiramphus sanctus*	G				16.7	2.9	20	7.7	11.5	0.519 (3.63)
Red-backed Kingfisher (3) *Todiramphus pyrrhopygius*	G					5.9		3.9		
Azure Kingfisher (1) *Alcedo azurea*	Q				16.7					
Rainbow Bee-eater (26) *Merops ornatus*	A	5.3	100		33.3	17.7	80	19.2	16.1	0.505 (12.41)
Dollarbird (13) *Eurystomus orientalis*	A		100	25	33.3		20	15.4	7	0.385
Singing Bushlark (9) *Mirafra javanica*	G							3.9	18.4	
Black-faced Cuckoo-shrike (23) *Coracina novachollandiae*	I	10.5				14.7	40	15.4	23	0.566 (7.33)
White-bellied Cuckoo-shrike (14) *Coracina papuensis*	I	5.3		37.5		8.8	20	11.5	7	0.465 (12.87)
White-winged Triller (32) *Lalage tricolor*	I	10.5			33.3	2.9	20	30.8	41.4	0.57
White-browed Robin (1) *Poecilodryas superciliosa*	I				16.7					
Lemon-bellied Flycatcher (1) *Microeca flavigaster*	I								2.3	
Jacky Winter (2) *Microeca leucophaea*	I				16.7				2.3	
Rufous Whistler (34) *Pachycephala rufiventris*	I	5.3	100		66.7	11.8	20	15.4	43.7	0.518 (3.78)

Table 2 (cont.)

Bird Species	Feeding Niche	Plant Communities (refer Table 1)								Habitat Breadth
		Mesa rim & escarpment		Riverine		Mesa Top		Plains		
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Sandstone Shrike-thrush (4) *Colluricincla woodwardi*	I	21.1								
Grey Shrike-thrush (7) *Colluricincla harmonica*	I		100			2.9	20		9.3	0.191 (2.75)
Restless Flycatcher (9) *Myiagra inquieta*	I		100		50	2.9	20	3.9	4.6	0.299
Leaden Flycatcher (2) *Myiagra rubecula*	I	10.5								
Northern Fantail (4) *Rhipidura rufiventris*	I	21.1								
Wille Wagtail (13) *Rhipidura leucophrys*	G				33.3	2.9		3.9	20.7	0.299 (3.99)
Grey-crowned Babbler (31) *Pomatostomus temporalis*	G				16.7	11.8	20	19.2	46	0.492
Golden-headed Cisticola (11) *Cisticola exilis*	I							34.6	4.6	
Rufous Songlark (18) *Cinclorhamphus mathewsi*	I	5.3			16.7	14.7		19.2	14	0.563
Purple-crowned Fairy-wren (1) *Malurus coronatus*	I			12.5						
Variegated Fairy-wren (1) *Malurus lamberti*	I	5.3								
Red-backed Fairy-wren (17) *Malurus melanocephalus*	I	5.3				14.7		19.2	14	0.438 (8.78)
Weebill (39) *Smicrornis brevirostris*	I	31.6		50		38.2		46.2	9.2	0.538 (5.65)
White-throated Gerygone (6) *Gerygone olivacea*	I	10.5				2.9		7.7	2.3	0.378
Varied Sittella (5) *Daphoenositta chrysoptera*	I							7.7	7	
Black-tailed Treecreeper (9) *Climacteris melanura*	I				16.7	2.9	20	11.5	7	0.516
Silver-crowned Friarbird (29) *Philemon argenticeps*	B	31.6				47.1	20	23.1		0.442
Helmeted Friarbird (1) *Philemon buceroides*	B	5.3								
Little Friarbird (36) *Philemon citreogularis*	B	10.5		12.5		23.5	20	34.6	34.5	0.644 (3.31)
Blue-faced Honeyeater (12) *Entomyzon cyanotis*	B			25	33.3	5.9		7.7	9.3	0.435 (6.45)
Yellow-throated Miner (17) *Manorina flavigula*	B	5.3				14.7		3.9	23	0.47
Singing Honeyeater (12) *Lichenostomus virescens*	B						60	3.9	20.7	
White-gaped Honeyeater (8) *Lichenostomus unicolor*	B		100	25			20	7.7	4.6	0.26 (4.03)
Yellow-tinted Honeyeater (31) *Lichenostomus flavescens*	B	5.3			50	14.7	80	15.4	32.2	0.541
Black-chinned Honeyeater (2) *Melithreptus gularis*	B							7.7		
White-throated Honeyeater (9) *Melithreptus albogularis*	B	15.8		25		8.8		3.9		0.37 (2.42)
Brown Honeyeater (47) *Lichmera indistincta*	B	63.2		12.5	16.7	67.7	20	19.2	9.2	0.528 (12.81)
Bar-breasted Honeyeater (5) *Ramsayornis fasciatus*	B	5.3	100			5.9			2.3	0.16
Rufous-throated Honeyeater (16) *Conopophila rufogularis*	B		100		16.7		20		29.9	0.284 (2.21)
Banded Honeyeater (17) *Certhionyx pectoralis*	B	31.6				17.7		7.7	6.9	0.364
Mistletoebird (37) *Dicaeum hirundinaceum*	F	36.8	100	12.5		32.4	40	30.8	16.1	0.58 (5.84)
Red-browed Pardalote (4) *Pardalotus rubricatus*	I	5.3			16.7		20		2.3	0.364
Striated Pardalote (12) *Pardalotus striatus*	I	5.3		37.5		14.7		7.7	2.3	0.334 (8.63)
Crimson Finch (1) *Neochmia phaeton*	S							3.9		
Double-barred Finch (14) *Taeniopygia bichenovii*	S	5.3		12.5		14.7		7.7	11.5	0.564
Masked Finch (4) *Poephila personata*	S				16.7				7	

Table 2 (cont.)

Bird Species	Feeding Niche	Plant Communities (refer Table 1)								Habitat Breadth
		Mesa rim & escarpment		Riverine		Mesa Top		Plains		
		Victoria River Comm. Nos. 3, 9, 4, 12 n = 19	Bullita Comm. No. 21 n = 1	Victoria River Comm. Nos. 10, 11 n = 8	Bullita Comm. No. 20 n = 6	Victoria River Comm. Nos. 1, 2, 8 n = 34	Bullita Comm. Nos. 16, 17, 23 n = 5	Victoria River Comm. Nos. 5, 6, 7 n = 26	Bullita Comm. Nos. 14, 15, 18 n = 43	
Long-tailed Finch (3) *Poephila acuticauda*	S						40		2.3	
Pictorella Mannikin (1) *Heteromunia pectoralis*	S					2.9				
Olive-backed Oriole (7) *Oriolus sagittatus*	F				33.3				11.5	
Great Bowerbird (24) *Chlamydera nuchalis*	F	36.8	100		16.7	8.8	20	3.9	23	0.444
Australian Magpie-lark (29) *Grallina cyanoleuca*	G				16.7	8.8		34.6	34.5	0.486 (4.71)
Black-faced Woodswallow (28) *Artamus cinereus*	A	5.3				17.7	60	26.9	25.3	0.511
Little Woodswallow (8) *Artamus minor*	A						40	3.9	11.5	0.242
White-breasted Woodswallow (2) *Artamus leucorhynchus*	A								4.6	
Pied Butcherbird (36) *Cracticus nigrogularis*	G	10.5		12.5	16.7	38.2	20	15.4	32.2	0.684 (5.4)
Torresian Crow (13) *Corvus orru*	G			25		8.8		11.5	11.5	0.421
Total Number Species (104)		36	13	28	31	54	34	63	72	
Mean Species Richness per quadrat (100 m x 100 m)		5.7	—	1.9	8.8	6.0	4.8	8.0	8.0	

Comparison of sites by classification of bird species composition

The dendrogram of the similarity of bird species composition of the 153 sites is shown in Fig 2. After inspection of bird species membership and associated habitat parameters it was decided to truncate the dendrogram at a dissimilarity of 1.6 which resulted in 7 bird groups.

By grouping vegetation communities with similar habitat characteristics, broad relationships were established between bird group and habitat (mesa rim, riverine, mesa top and side, and plains) and area (Bullita or Victoria River) (Table 3). The proportions of birds assigned to particular food niches for each of the bird groups obtained from the dendrogram (Table 4) can be related to the group structures in Table 3.

Group 1 (Table 3) was significantly associated with riverine habitats at Bullita. Birds from this group comprised seed eaters and ground insectivores (Table 4) and commonly included the Yellow-tinted Honeyeater, Peaceful Dove, Pied Butcherbird and Black-faced Cuckoo-shrike.

Group 2 was significantly associated with the plains communities at Bullita and Victoria River with only minor occurrences in other habitats. There was a high proportion of foliage gleaners (insectivores) including the Singing Bushlark, Golden-headed Cisticola and Yellow-throated Miner.

Group 3 was significantly associated with riverine habitat at Victoria River where it was more extensive than that at Bullita. Foliage insectivores as well as seed eaters were

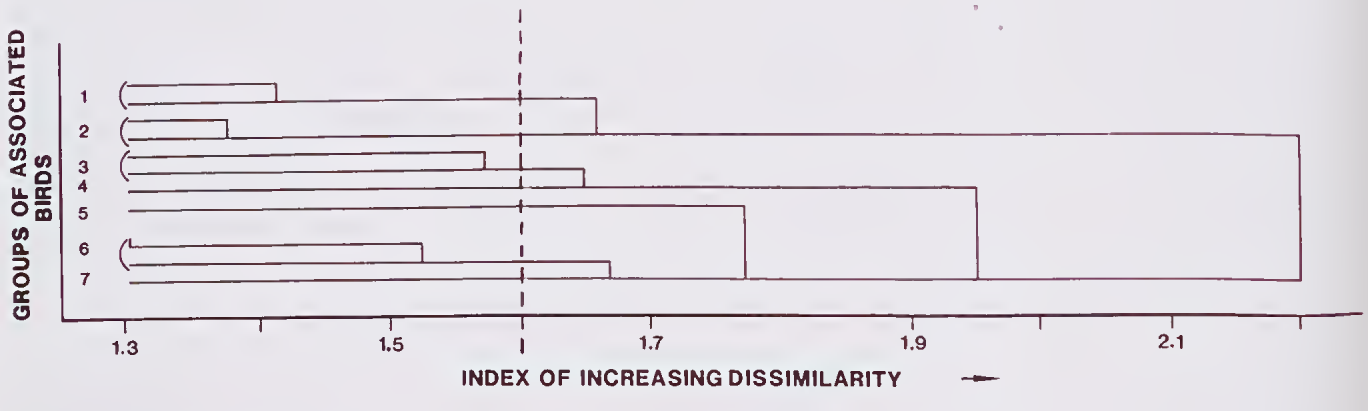

Figure 2. Dendrogram showing the relationship between bird presence/absence samples at the 7 group level using the Bray Curtis similarity measure and the WPGMA sorting strategy.

most commonly found and included the White-bellied Cuckoo-shrike, Peaceful Dove and Bar-shouldered Dove.

Group 4 was significantly associated with the mesa tops at Bullita, where *Grevillea angulata* bushes were commonly in flower, but also on the plains there. The feeding groups most frequently occurring were the fruit and insect eaters, the aerial insectivores and the feeders at flowers and were represented by the Great Bowerbird, Mistletoebird, Rainbow Bee-eater, Little Woodswallow and Singing Honeyeater.

Groups 5 and 7 were both significantly associated with the closed forest communities on the mesa rims and escarpments at Victoria River, with group 5 also occurring on the mesa tops there, with their floristically and structurally distinct open-woodlands. These groups comprised feeders at flowers and were characterized by the Brown Honeyeater, Silver-crowned Friarbird and Rainbow Lorikeet.

Table 3

Association between groups of related birds (from dendrogram, Fig 2) and the vegetation and topography of Gregory National Park, NT. (Numbers in brackets are the plant communities from Table 1).

Vegetation, Geology and Topography		Groups of related birds 1	2	3	4	5	6	7	No. birds
Mesa Rims & Escarpments	Victoria River (3,4,9,12)	0	0	1	1	9 ***	5	3	1
	Bullita (21)	0	0	1	0	0	0	0	3
Riverine	Victoria River (10,11)	1	0	5 ***	0	1	1	0	0
	Bullita (20)	3 ***	1	2	0	0	0	0	1
Mesa Top	Victoria River (1,2,8)	4	3	3	0	12 ***	10	2	2
	Bullita (16,17,18,23)	2	1	1	3 ***	0	1	0	3
Plains	Victoria River (5,6,7)	2	9	3	0	2	8	2	1
	Bullita (14,15)	7	24	3 ***	4	2	0	0	0
		19	38	19	8	26	25	7	11

*** significant associations ($P < 0.05$) using one sample chi-square analysis

Group 6 was not associated with any particular habitat although it was found on the mesa tops and plains at Victoria River and was characterized by the foliage gleaning Weebill.

Comparison of vegetation communities by ordination of bird species composition

The ordination of the percent occurrence of birds by the 20 vegetation communities is presented graphically in Fig 3. On the same diagram the habitats are identified as occurring at Bullita or Victoria River and as mesa, plain, riverine or hill. Those communities on mesas are subdivided further into top, side-slope, rim or ephemeral watercourses. The communities are enveloped into gross vegetation/landform/area types where appropriate to aid interpretation.

Superimposed on the diagram are values of percent foliage cover of the upper stratum and floristic DCA 1 score from the first axis (taken from Bowman *et al.* 1988).

Broad quantitative relationships between the vegetation parameters of foliage cover and floristic composition as measured by the floristic DCA 1 score (from Bowman *et al.* 1988) are apparent. (The floristic DCA 1 score was related to topographic position through its influence on moisture status.) Generally habitats with high DCA 1 and DCA 2 scores were associated with vegetation communities with high floristic DCA 1 scores, which represents high moisture status and associated high canopy covers. Habitats with low DCA 1 and DCA 2 scores had low floristic DCA 1 scores, indicating drier sites and associated low canopy covers.

There was also a clear differentiation between habitats from the Bullita area which generally had low DCA 1/high DCA 2 scores and those from the Victoria area which had high DCA 1/low DCA 2 scores. This trend over-rode the relationship between the floristic and structural characteristics and bird composition. For example, the sites from mesa rims at Bullita (community 21) and Victoria River were floristically and structurally distinct from other plant communities due to the increased moisture run-off associated with the habitat. The bird composition in the vegetation of the Bullita mesa rim was more similar to that in the floristically different sites on the mesa tops (community 16) than to the floristically and structurally similar vegetation types at Victoria River (communities 3, 4 and 12). The riverine communities show a wide variation in composition of bird assemblages but the sample sizes per community were low (10: n=1, 11: n=7).

Comparison of feeding niche, species richness and habitat breadth.

Granivores [S] (n=21) and species feeding on insects in shrubs and trees [I] (n=29) were the most common (Table 1). Only 3 of the 8 niche groups showed significantly

Table 4

Mean proportions (%) of birds assigned to particular food niches compared with groups of affiliated birds (from dendrogram Fig 2). Within a column, the letters a, b, and c indicate the means that do not differ from each other at P=0.05 level using SNK test.

Bird Groups	Aquatic	Raptorial	Seeds	Insects (ground)	Flowers	Insect (aerial)	Fruit/insects	Insects (foliage)
1	0.2	3.4	28.8a	20.0a	24.1b,c	9.4b	1.9c	16.7b
2	0.3	2.7	13.1c	16.1a,b	22.6c	6.8b	4.9c	33.6b
3	2.6	4.1	29.6a	7.2c	18.1b,c	7.3b	3.3c	27.8b
4	—	0.8	5.6c	—	22.4b,c	20.9a	31.9a	18.4b
5	—	2.1	9.4c	7.7c	45.6b	1.1b	8.8c	25.3b
6	—	1.8	12.7a,b	6.5c	13.8b,c	4.8b	16.3a,b	39.3a
7	—	—	3.6c	4.1b,c	66.2a	—	12.0b,c	14.1b
	n.s.	n.s.						

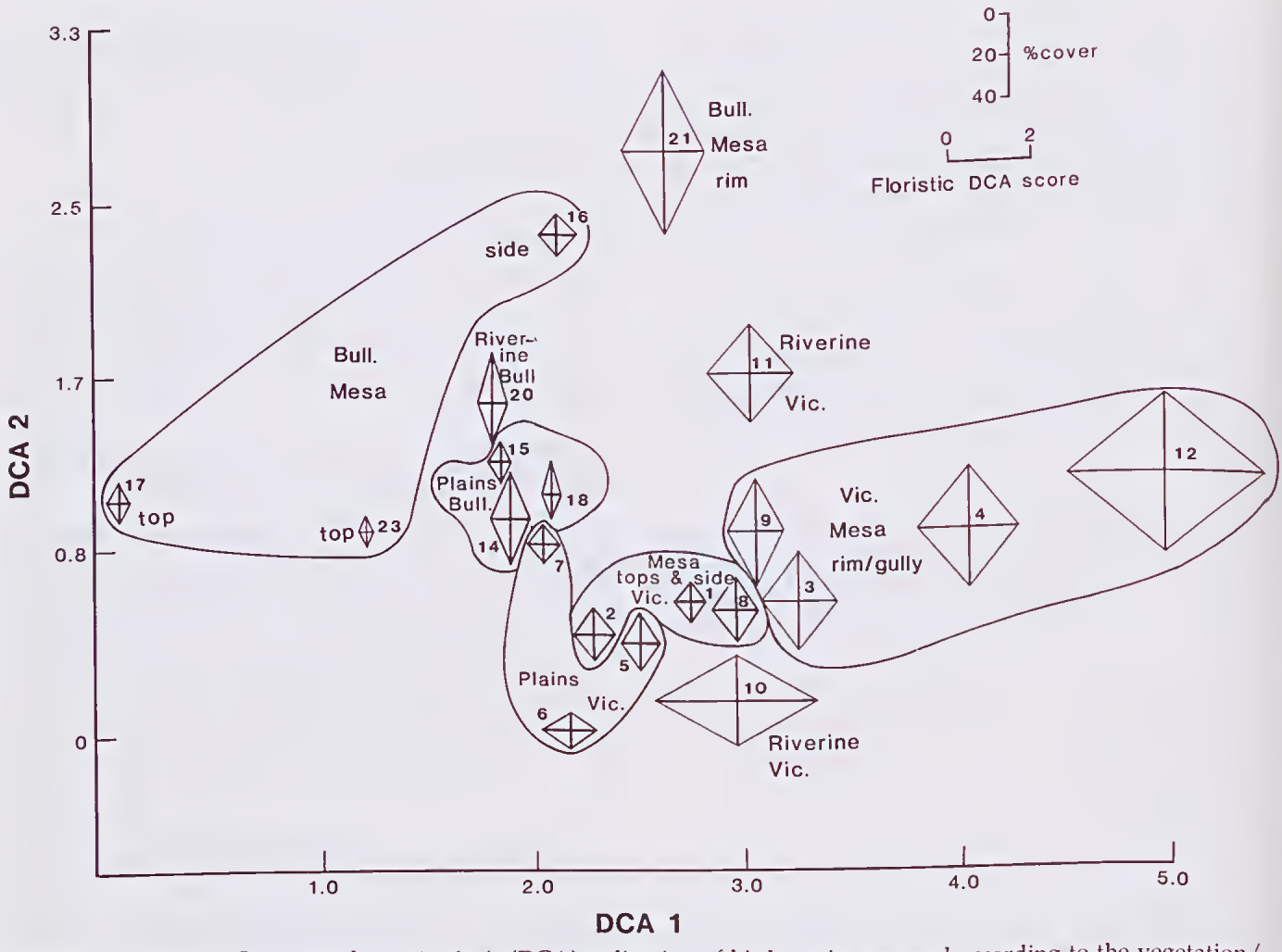

Figure 3. Detrended Correspondence Analysis (DCA) ordination of bird species grouped according to the vegetation/landform classification of Bowman *et al.* (1988). (The floristic DCA scores and % canopy cover from Bowman *et al.* have been superimposed on the bird DCA scores; the heights of the diamonds represent % canopy cover of dominant layer; widths of diamonds represent the floristic DCA score; Vic.= Victoria River crossing region (towards north-eastern end), Bull.= (more central) Bullita region, of Gregory National Park, Northern Territory.)

Table 5

Mean proportions (%) of birds assigned to particular food niches compared with bird groups sorted according to vegetation categories of Bowman *et al.* (1988). Within a column, the letters a and b indicate means that do not differ from each other at P=0.05 using SNK test.

Location	Feeding Niche							
	Aquatic (n=5)	Raptorial (n=12)	Seeds (n=21)	Insects (ground) (n=12)	Flowers (n=16)	Insects (aerial) (n=6)	Fruit/insects (n=3)	Insects(foliage) (n=29)
Mesa Rims + Escarpments								
Vic.	0	0.8	6.1b	33.5a	38.1	5.1	19.6b	33.5
Bullita	0	0	15.4a,b	23.1a,b	23.1	15.4	15.4a,b	23.1
Riverine								
Vic.	1.2	0	36.0a	24.4a,b	14.8	2.0	2.5a,b	24.4
Bullita	0	0	27.1a,b	30.3a,b	18.6	8.5	5.7a,b	30.3
Mesa Tops								
Vic.	0	3.3	12.5b	10.3b	36.0	7.5	8.5a,b	26.2
Bullita	0	6.7	10.7b	34.4a	18.0	17.7	7.0a	23.7
Plains								
Vic.	1.8	2.4	19.7a,b	30.6a	21.4	6.3	4.3a	30.6
Bullita	0.1	2.0	14.3b	27.5a	27.2	8.0	11.7a,b	33.8
	n.s.	n.s.			n.s.	n.s.		n.s.

different proportions when sorted according to the vegetation categories (Table 5). These were the seed eaters which were most abundant in riverine habitat, and both ground feeding insectivores and fruit eaters which were most abundant in the plains vegetation (Table 5). A stronger association occurred when the same feeding categories were compared with the groups of birds derived from the dendrogram (Table 4) as described above. Fruit-eaters were

Table 6
Number of communities supporting birds when they are clumped according to feeding niche.

Feeding Niche	Mean no. of communities	Standard deviation
Seed eaters (S) (n=21)	3.3	1.9
Insect gleaners (I) (n=29)	3.2	2.0
Aquatic (Q) (n=5)	1.0	0
Raptorial (R) (n=12)	1.6	0.9
Ground insectivores (G) (n=12)	3.7	2.0
Aerial insectivores (A) (n=6)	3.8	2.6
Flower feeders (B) (n=16)	4.2	1.6
Fruit & insect feeders (F) (n=3)	5.3	2.9

found in more communites (mean=5.3; s.d.=2.9) than other groups (Table 6). The least widely distributed were the aquatic and raptorial species (Table 6).

The mean species richness per hectare was calculated for 7 habitats and ranged from 1.9 (riverine at Victoria River) to 8.8 (riverine at Bullita) (Table 2). Overall the plains habitat was the richest in species with an average of 8.0 per hectare compared with 5.4 for mesa tops and riverine habitats (Table 2). Where habitat breadths were calculated, they ranged from 0.16 (Bar-breasted Honeyeater, recorded 5 times) to 0.716 (Peaceful Dove); the most common species (Brown Honeyeater) had a habitat breadth of 0.53 (Table 2). For those species also occurring in the Darwin region, the re-calculations from Woinarski *et al.* (1988), ranged from 2.42 for the White-throated Honeyeater to 12.87 for the White-bellied Cuckoo-shrike.

There were 27 species that were recorded in both the Darwin region and three or more times in this study (Table 1). There was a significant positive correlation between the habitat breadths in both regions (r_s=0.67, n=27, p<0.001).

Discussion

Some of the birds recorded here were seen infrequently. For example, raptors and aquatic species are large birds with large home ranges and may have been undersampled using the method above. In addition, some birds are seasonally nomadic in the Top End of the Northern Territory (the raptors); are nocturnal; are restricted to certain habitats (rock-pigeon, Sandstone Shrike-thrush, Purple-crowned and Variegated Fairy-wrens, Crimson Finch); are migratory (Channel-billed Cuckoo); or, were in areas that were sampled infrequently (the aquatic species).

The topography as well as floristics and vegetation structure were correlated with the distribution of the birds. For example, birds that were found on the plains were found also on the adjacent low hills even though they differed floristically; and bird communities on the mesa tops and sides were similar to some of those in the closed forest on adjacent escarpments even though the vegetation was floristically and structurally distinct. This could be expected given the mobility of birds and also the opportunistic attraction by some (e.g. honeyeaters, woodswallows, lorikeets) to flowers in general rather than flowers of a particular species.

The contrast between the riverine habitat and non-riverine was greater at Bullita which is drier than at Victoria River. This could account for the riverine species richness at Bullita being more than 4 times greater than at Victoria River. The plains may have been the richest of all the habitat types recorded in this study because they were more extensive and so have developed a larger avifauna over time. This is reflected in the plant communities of the Top End where the savannah woodlands are the richest in terms of plant species number (Bowman *et al.* 1988a). The most frequently recorded bird species, the Brown Honeyeater, was not the most widely distributed across vegetation types. The Peaceful Dove was the characteristic species of the general region.

From the comparison of the habitat breadths of birds common to the Darwin region (from Woinarski *et al.*) and Gregory National Park, it appears that each individual species will behave in the same broad way to using habitat even though the floristics and structure may vary.

There were distinct gradients in the distribution of birds that reflected the climatic, topographic and vegetation differences between the drier, more open landscape of Bullita and the steeper escarpment country at the Victoria River end. For example, there is a better representation of raptors, parrots and acanthizids in the Victoria River area. The differences may have been better defined if numbers of individuals rather than just presence had been recorded. Any future survey should be designed to overcome this.

Classifying individual samples by bird composition produced groups that had gross associations with habitat. These bird/habitat patterns were better defined when bird composition was averaged within vegetation groups because it was found, with a few exceptions, that similar vegetation types had similar bird composition.

To improve this survey method, samples should be more evenly distributed among the categories defined on the aerial photographs during the initial planning stage. The problem of sampling within 'perceived' habitat types was overcome because the maximum number of areas discernible on the landsat images were sampled. By using one observer for all bird samples, the variability due to observer bias was minimized (compared with Friend & Dudzinski 1981; Block *et al.* 1987). The reliability of any survey can be increased with larger samples. The number of samples varies between studies from 1000 (Woinarski *et al.* 1988) to 13 areas (and undefined number of samples) (Kikkawa *et al.* 1981). Repeated sampling would define differences that might arise because of seasonal variation. As in the case of this study, a pre-determined 'one off' census, birds should be recorded at a time when the maximum number of species typical of the area is likely to be present. The survey methods used in this study satisfied the aims of the study and are appropriate if time-efficient surveys are required especially in areas that have never been studied before.

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